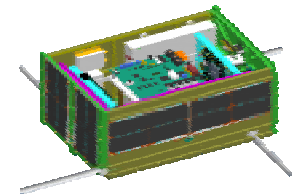


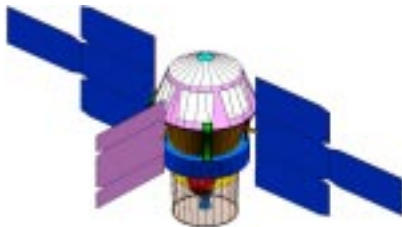


Overview of OBPR Free Flyer System Concept

Ron Leung
NASA/GSFC Code 594



Free Flyer Research Workshop
December 2-3, 2003



Technical Contributions
Al Lieberman
NASA/GSFC Code 594



OBPR Free Flyer Theme



- Develop a dedicated Free Flying (unmanned) space-borne research capability for OBPR
- Need for spacebased research capability (Biological and Physical) that is complementary to the Shuttle or ISS
- Research would utilize hazardous environments not encountered on Shuttle or ISS
- Mission duration, orbital parameters, etc driven by research needs
- Free Flyer Platforms address
 - Research requirements and needs
 - Technology development
 - Education and outreach
- Would build on extensive experience from
 - Biosatellite (1960), Bion/Foton, Lifesat (study), Skylab, STS, MIR and ISS



OBPR Free Flyer Technical Activity Last 2 Years



- 2002
 - Free Flyer ARC Workshop (June 2002)
 - OBPR Research Centers
 - NASA/GSFC
 - Research drivers for Free Flyer (FF)
 - Requirements
- 2003
 - 4 GSFC INTEGRATED MISSION DESIGN CENTER (IMDC) STUDIES
 - NASA-wide participation (January – August)
 - Preliminary Free Flyer presentation to NASA Headquarters (February)
 - M. Kicza & Directors
 - Authority to Proceed
 - Coordination meetings
 - Expendable Launch Vehicle (ELV) Office (HQ/KSC) (June)
 - Space Life Sciences Experiment Research & Processing Laboratory (formerly SERPL) at KSC (June)
 - Utah Test & Training Range (UTTR) (July)
 - Conceptual Free Flyer Heavy recovery site

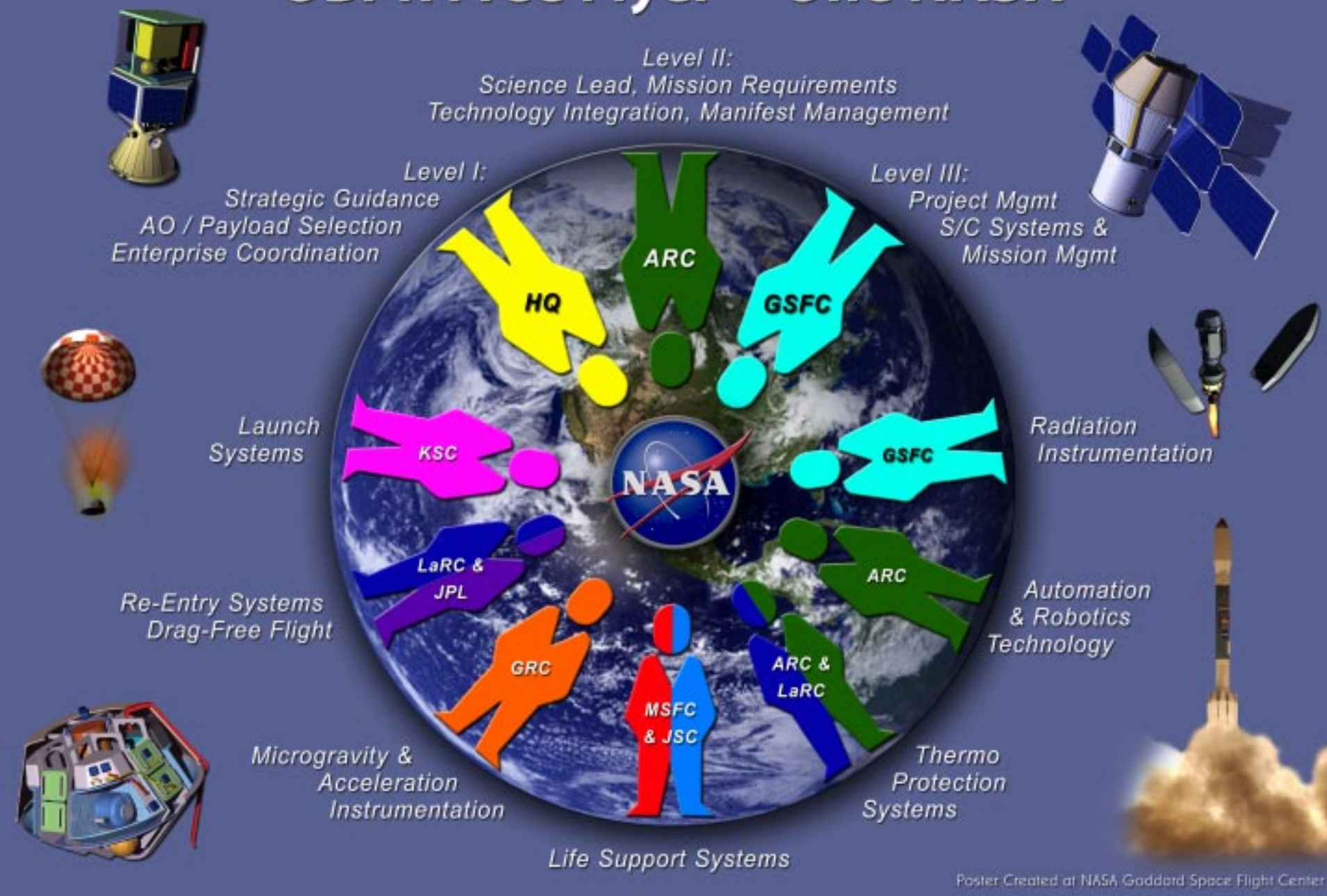


GSFC Integrated Mission Design Center (IMDC) Studies



- GSFC IMDC Free Flyer Medium Study #1 (13 to 17 Jan 2003)
 - High Earth Orbit, one way/no return, beyond Van Allen Belts, 10-e5 G
- GSFC IMDC Free Flyer Heavy Study #2 (10 to 14 Feb 2003)
 - Low Earth Orbit Return, payload recovery, quiescence
- GSFC IMDC Free Flyer Heavy RV Study #3 (14 to 18 April 2003)
 - Follow-on to previous study (#2)
 - Concentrated on RV conceptual design and earth return
 - Low Earth Orbit Return, payload recovery, quiescence
 - Environmentally controlled RV payload volume
 - Provisions for live specimens and power through all mission phases
- GSFC IMDC Free Flyer Heavy Study #4 (4 to 7 August 2003)
 - Advanced System Concept Study

OBPR Free Flyer — One NASA



Poster Created at NASA, Goddard Space Flight Center



Free Flyer Expertise For Studies



- Science
 - ARC
 - Fundamental Biology
 - Fundamental Space Biology
 - Previous Free flyer Experience
 - Requirements
 - JSC
 - Biotechnology
 - MSFC
 - Physical Science
 - Material Science
 - JPL
 - Fundamental Physics
- Engineering
 - GSFC
 - Integrated OBPR Mission Free Flyer IMDC Studies
 - System & Subsystem S/C Engineers
 - JPL, LARC, ARC, MSFC, GRC
 - System & Subsystem Engineers



Free Flyer Assumptions & Goals



- Studies
 - reference experiments derived from FF workshop (June 2002)
 - developed mission & S/C concepts
 - concepts only, at this point, not a design baseline
 - open discussion and feedback sought from user community
 - subject to change as a result of this workshop
- Launch vehicle
 - assumed FFM & FFH requirements could be satisfied by Delta II for study
 - Proven reliable launch vehicle
 - reduces mission costs from assuming larger launch vehicle
- Lowest possible orbit/inclination to accomplish mission
 - reduces mission costs
- FFH Re-entry Vehicle terrestrial recovery (CONUS)
 - reduces mission/operational costs
- OBPR FFM & FFH spacecraft
 - similar copies in each class
 - assumed mass production techniques employed
 - reduces mission/operational costs



Free Flyer (FF) Total Payload Reference Concept Capabilities



| ITEM | FF Medium (FFM) | FF Heavy (FFH) | Secondary Payloads of Opportunity |
|--------------------|--|-------------------------------|-----------------------------------|
| Operational (days) | 60 design (1), 180 goal | 60 design (1), 90 goal | TBD (ex. hrs to days) |
| microG (g) | 10-e5 | 10-e5 | TBD |
| Orbit | Circ, 70000 km (12 Re), 28.5 deg incl | Circ, 550 km 40.5 deg incl | depends on primary payload |
| Mass (kg) | 170 (2) | 920 (2) | 0 to 50 |
| Volume (m3) | 1.55 (2) | 2.5 (2) | TBD(ex. 0.009 to 0.09) |
| Power (kw) | 0.25 | 2 | TBD(ex. 0.002 to 0.060) |
| Thermal (deg c) | 25 | 20 | TBD(ex. -23 to -12)] |
| Data (kbps) | 58 | 313 | TBD (ex. 4 to 40) |

- (1) For the FFM & FFH missions the limit on mission duration are the payload consumables required. The expected mission spacecraft lifetime is ≥ 2 years.
- (2) FFM & FFH Science payload mass includes payload structure mass & volume



FFM Reference Payload Requirements



Provided by OBPR Research Centers
Derived from Research Workshop June 2002

| PAYLOAD | MASS | DATA | VOLUME | POWER | OPERATIONAL | MICROG | ORBIT |
|----------------------------------|--------|--|---------------------|-------|-----------------------|------------------|-------|
| PS1Biosentinel Devices | 5 kg | 1 Mb/day for 10 days | 0.05 m ³ | 50W | 30-60 days | 10 ⁻³ | HEO |
| PS4 Diffusion Measurements | 100 kg | High quality video – TBD frequency | 0.5 m ³ | 75W | 21 days duration | 10 ⁻⁴ | N/S |
| PS12 Microgravity Crystal Growth | 40 kg | Video frames + control / housekeeping data | 0.5 m ³ | 20 W | 1 – 6 months duration | 10 ⁻⁵ | N/S |
| FB2 Yeast Radiation | 26 kg | Low rate | 0.5 m ³ | 100 W | 30 + days | 10 ⁻³ | HEO |
| TOTAL PAYLOAD | 170 kg | Video, command / control, housekeeping | 1.55 m ³ | 250 W | 60 days | 10 ⁻⁵ | HEO |



FFM Requirements



- Mission Driving:
 - Provide payload with exposure to Galactic Cosmic Rays (GCR's) as would be experienced in interplanetary space.
 - Capable of maintaining a micro-gravity environment ($\leq 10^{-5}$ g) once payload is delivered to orbit.
 - Provide a mid-sized platform (<1000 kg) on which to fly 4 representative experiments to the GCR and microgravity environment.
 - Provide late access on launch pad (L – a few hours) to load biological samples and materials as required.
- Mission Derived Requirements/Parameters
 - Orbit:
 - No inclination requirement, May be elliptical or circular
 - Spacecraft:
 - Power, Communication, Attitude Control, C&DH, Thermal Control
 - Experiment Vent and Vacuum ports



FFM Mission



Total Vehicle mass:

1091 kg

Payload Module mass:

170 kg

Launch Vehicle:

Delta II-H

Orbit:

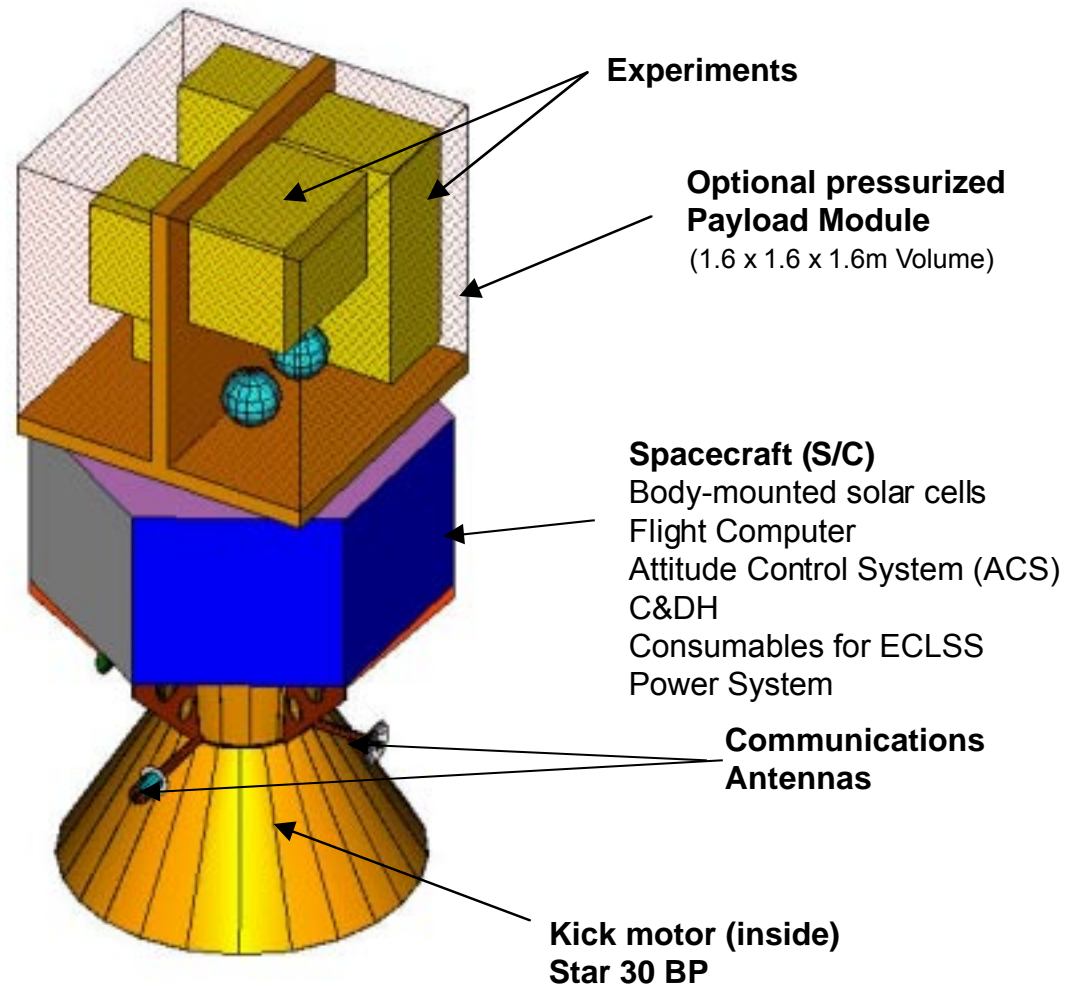
**HEO ($\approx 70,000$ km), circular
@ 28.5°**

Continuous Quiescence:

Target is $\leq 10^{-5}G$

Data Collection:

**Telemetric
(no spacecraft return)**





FFM Summary



- 4 reference payloads - Mixed Physical & Biological payloads
 - Total mass 170kg, volume 1.55 m³
- Payloads are not returned to the Earth
- 12 Re x 28.5 deg inclination circular orbit – GCR exposure, 10-e5 micro g on orbit
- Mission Life - 60 day design, 180 day goal
- Late access to payload on launch pad (biological samples & materials)
- Attitude Control System - Inertial Pointing S/C
- Mechanical - modular concept, aluminum, heritage S/C fixtures, brackets and fittings, 1.6x1.6x1.6 m³ total payload volume
- Data - Average data rate 58 kbps, s band telemetry at 2 Mbps, s band commanding at 2 kbps, 2 days of data storage 10 Gbits
- Thermal - common cold plate, payloads maintained at 25 deg c
- Pressurized payload volume possible - no maintenance of atmospheric composition



FFH Reference Payload Requirements



| PAYLOAD | MASS | DATA | VOL. | POWER | OPERATIONAL | MICROG | ORBIT |
|--|-----------------|---|--------------------------------|-------------|-----------------------------|--|---------------|
| PS06 High Temperature Materials Processing | 120 kg | Low rate; some video frames, 1 kbps | 0.5 m ³ | 300 – 500W | 60 days | 10 ^{-7*} | N/S |
| SPD2 Commerical Protein Crystal Growth | 32 kg | High quality video – TBD frequency, 1 Gb / day | 1 MDLE (0.054 m ³) | 128 W | 50 days | ≤10 ⁻⁴ | N/S |
| PS03 ISLES | 300 kg | 7 channels x 20 Hz, downlink 1/day, 2.2 kbps | ~1 m ³ | 50 - 200 W | 60 days, needs vent for LHe | ≤10 ⁻⁵ | N/S |
| SPD6 Vulcan | 128 kg | Housekeeping data +uplink of Commands, 1 kbps | 4 MDLE (0.22m ³) | 350 - 900 W | ≥10 days, needs vacuum | ≤10 ⁻⁴ | N/S |
| FB03 Mice Radiation | 300 kg | Low rate data 1kbps, (Video?) 3.6 Mbps for 80 min per day | 10 MDLE (0.54 m ³) | 400 W | 30 days | 10 ⁻³ | N/S |
| PS02 3D Tissue Model Radiation | 140 kg | <1Mb/day + video of 3.6 Mbps for 30 min every 3 rd day | 2 MDLE (0.11 m ³) | 325 W | 60 days | 10 ⁻³ | N/S |
| TOTAL PAYLOAD | 1020 kg Note | | ~2.5 m ³ | ~2 kW OAP | 60 days | 10-e5g nominal * 10 ⁻⁷ g requested | LEO 40 deg |

Note: Study results show <= 920 kg capability (payload structure included)
FF Research Workshop 12/2-3/03



FFH Driving Mission Requirements



- Provide a large (payload ~1000 kg) on-orbit laboratory on which to fly 6 representative experiment payloads to a microgravity environment in a LEO orbit.
- Capable of maintaining a micro-gravity environment (10-e5 g requirement, 10-e7 g goal) once payload is delivered to orbit.
- Provide payload re-entry capability to CONUS, reliability of hitting target landing area of 99.95%.
- Provide late access on launch pad (L – a few hours) to load biological samples and materials.
- Maintain the primary launch and re-entry load vector in the same direction.
- Maintain G-load throughout mission to less than 10 g.
- Maintain payload environment for ~12 hours after beginning of re-entry.



FFH Requirements/Mission Parameters (Derived)



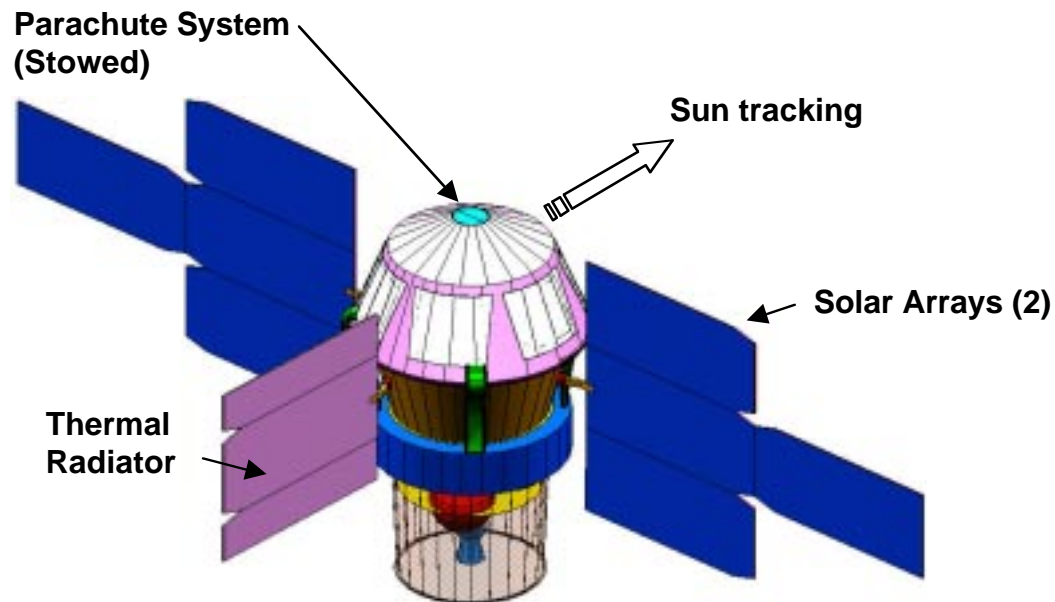
- Orbit requirements:
 - Inclination requirement driven only by landing range location (CONUS/UTTR assumed)
 - LEO desired to allow large mass to orbit
 - Must be suitable for maintenance of micro-gravity level, altitude high enough to minimize aerodrag
- Spacecraft (SC) Driving Requirements:
 - Redundancy required to reliably hit the target landing area
 - Design must maintain micro-g environment
- Re-entry Vehicle (RV):
 - Provide thermal protection for re-entry
 - House all payloads, ECLSS, support systems, parachute system
 - Provide vent and vacuum ports for payloads
 - Provide means for vehicle location during re-entry and after landing
 - Provide hatches for access on pad
 - Provide resources and thermal control for up to 12 hours after spacecraft separation
- Launch Vehicle:
 - Delta II desired to keep cost down
 - Provide late access to payloads on launch pad
- Landing Site:
 - Continental United States (CONUS) desired



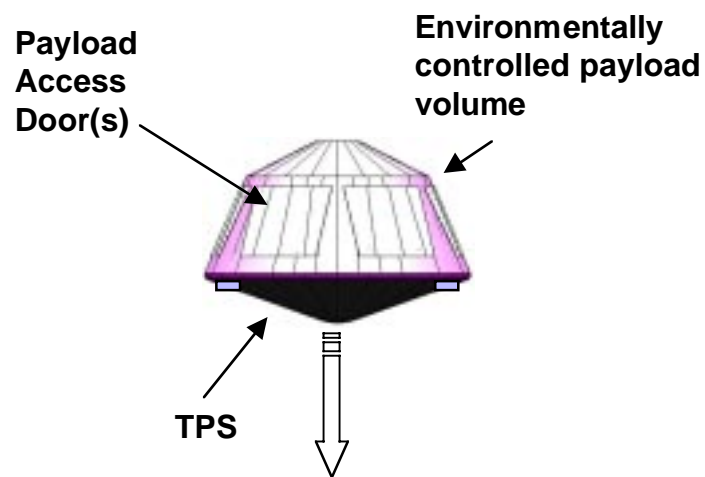
FFH Mission



Vehicle On-orbit Configuration

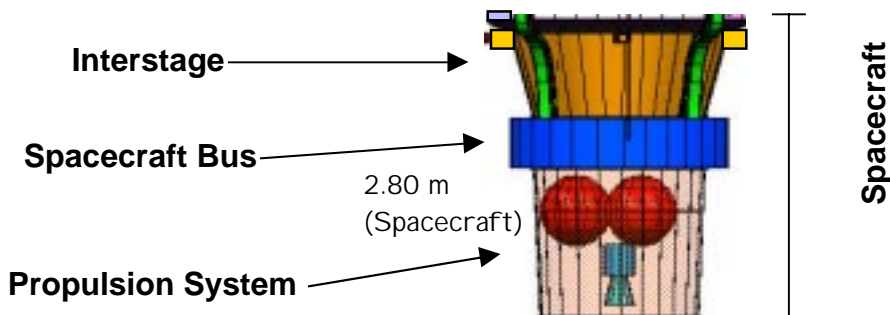


Recovery Vehicle (RV)



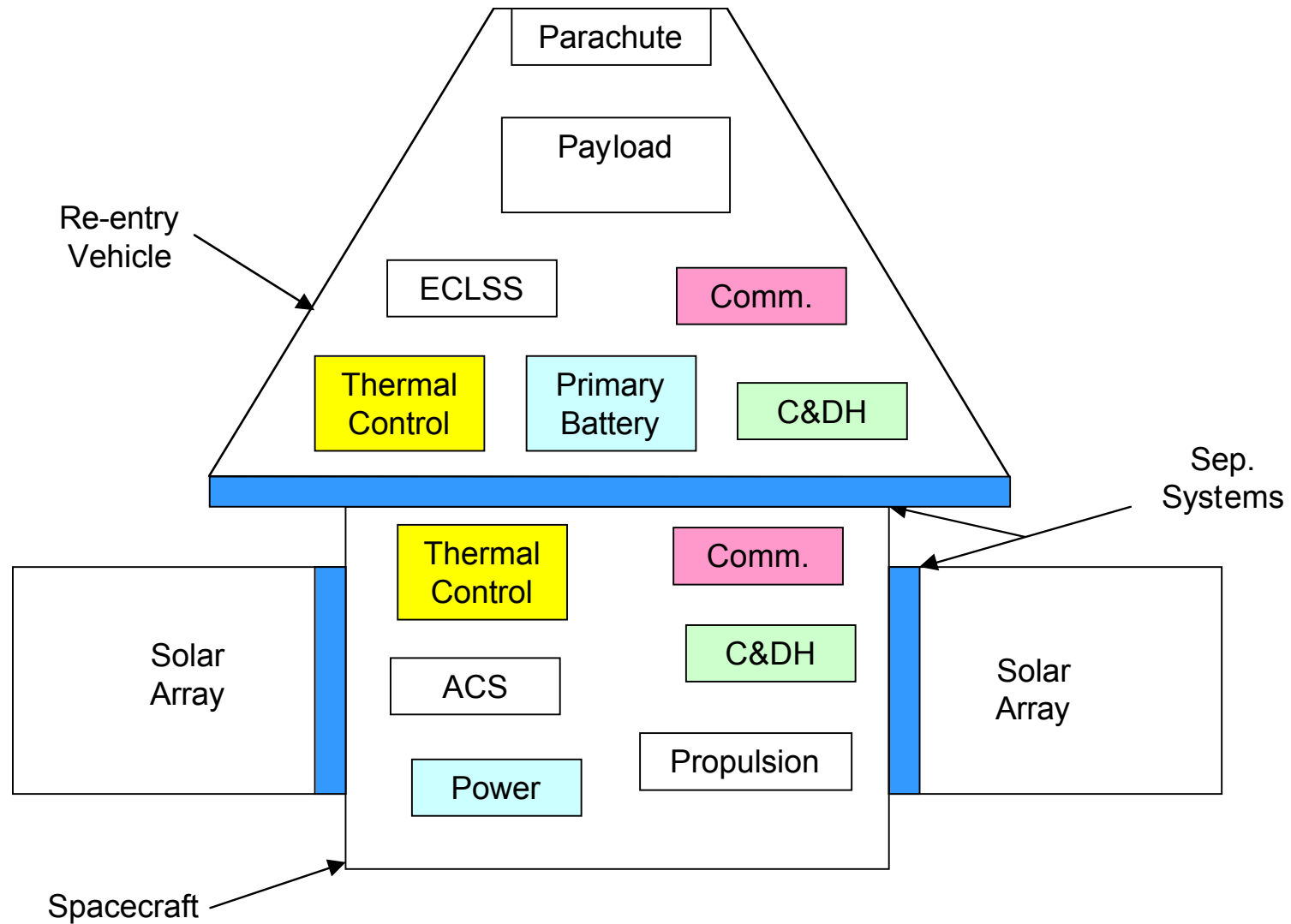
G-Vector when present is unidirectional

Total Vehicle mass: 3453 kg
RV mass: 1963.9 kg
Payload module mass 921 kg
RV Volume: 4.3 m³
Payload Volume : 2.5 m³
RV Diameter: 2.44m
Launch Vehicle: Delta II Heavy
Orbit: 550 km circular @ 40.5°inclination
Recovery: Utah Test & Training Range (concept)



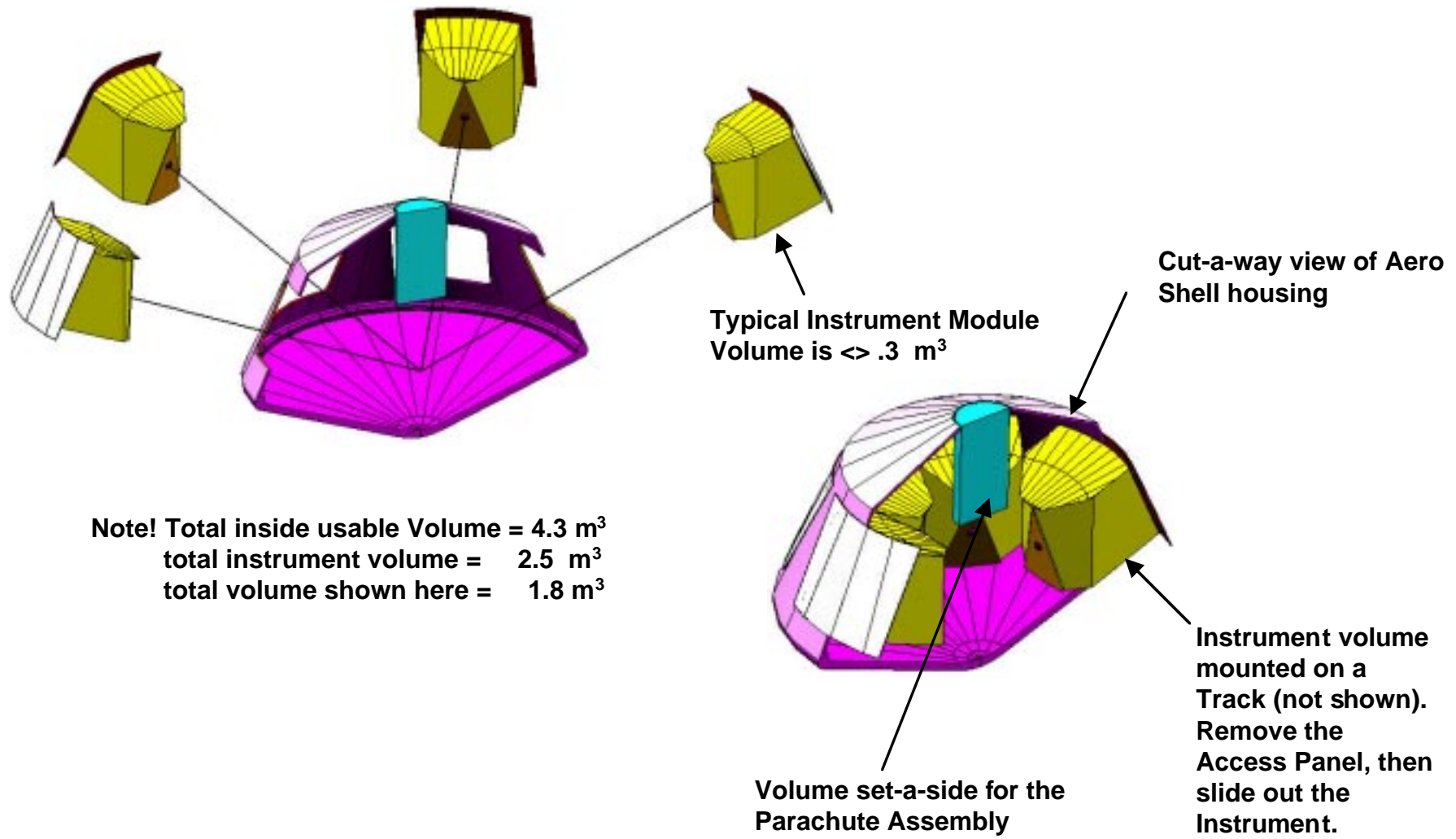


FFH Block Diagram Concept



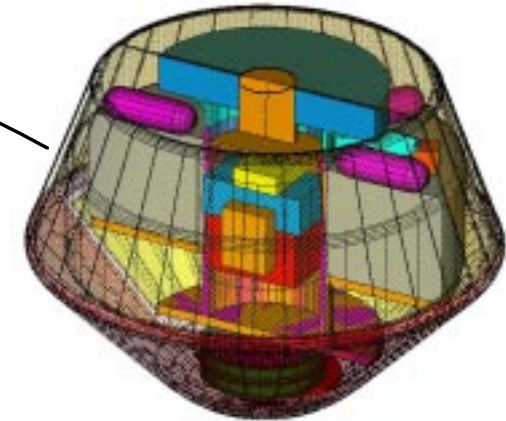
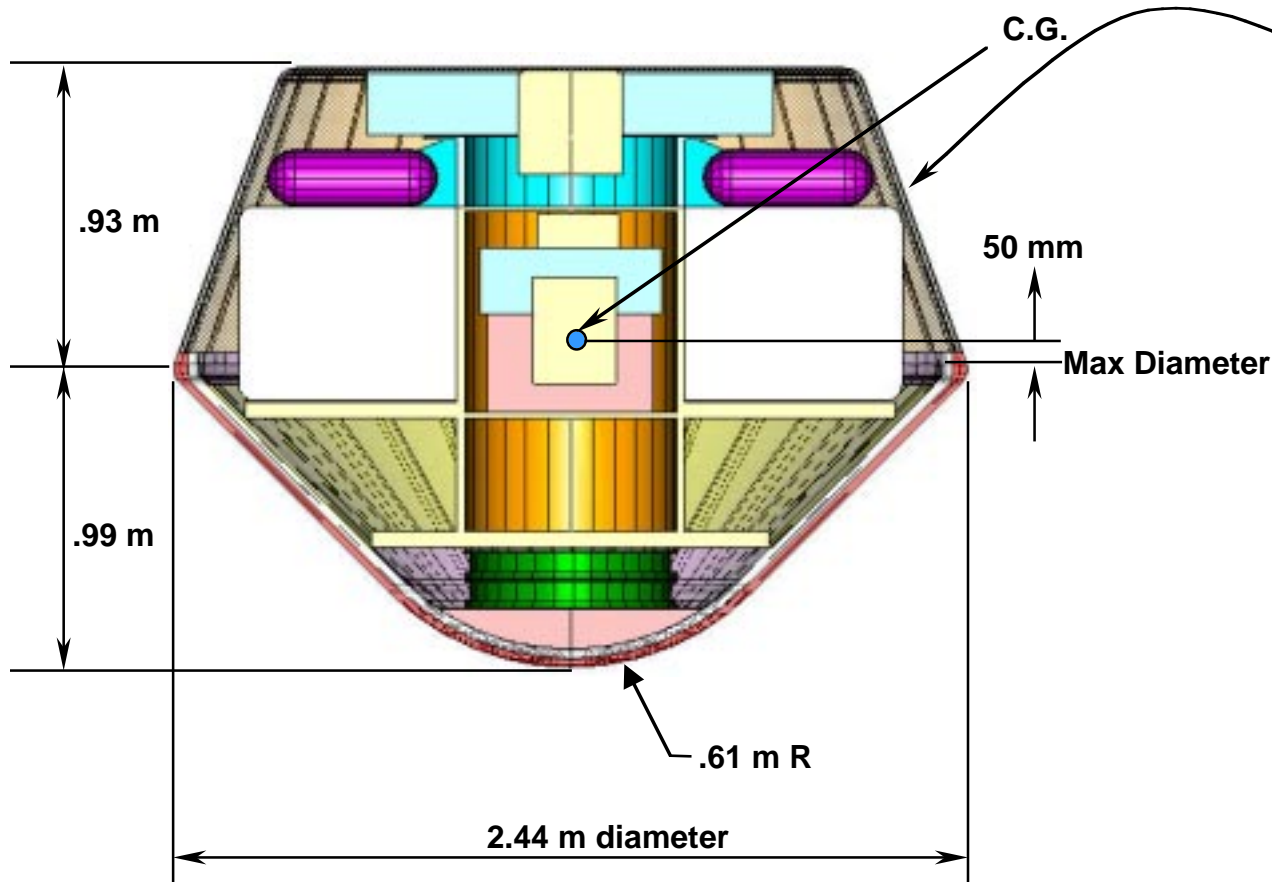


FFH Aeroshell & Payload Modular Concept





FFH Aeroshell & Toroidal Payload Concept



Volume of Aeroshell, For Reference only



FFH Summary



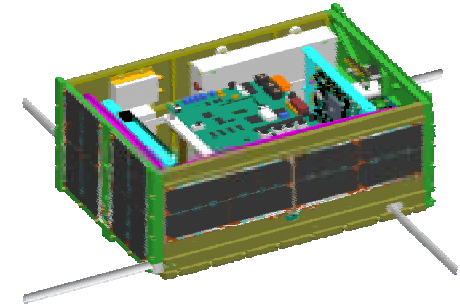
- 6 reference payloads - Mixed Physical & Biological payloads
 - Total mass ≤ 920 kg (structure included), volume 2.5 m³
- Payloads are returned to the Earth
- 550 km x 40 deg Circular orbit – 10-e5 micro g on orbit
- Mission Life - 60 days design, 90 days goal
- Late access to payload on launchpad (biological samples & materials)
- Attitude Control System - Inertial Pointing S/C
- RV Mechanical - modular or toroidal payload concept, aluminum honeycomb aeroshell, 2.5 m³ total payload volume
- Data - Average data rate 313 kbps, x-band telemetry at 20 Mbps, s band commanding at 2 kbps, 1.5 days of data storage 40 Gbits
- Thermal - common cold plate, payloads maintained at 20 deg c, TPS for re-entry aeroshell
- ECLSS - Provides atmospheric constituents, revitalization, monitoring, total pressure control, sensible heat control



Secondary Payloads of Opportunity



- Third class of flight opportunity under Free Flyer Program
 - 1 kg to 50 kg
- Small, self-contained OBPR research payloads
 - Technology demonstration/development
 - Education
 - Public Outreach
- High level concept only at this time
- Accommodated on other primary missions with excess margins
 - FFM, FFH and other possible NASA/DOD/commercial/international missions
 - Must meet mass, volume, power, data etc margins allotted by primary
- Assumed
 - No interference with primary mission
 - Accommodate orbital parameters of primary mission
 - Launch schedule of primary is sacrosanct
- Examples
 - Nanosatellites
 - Picosatellites





Free Flyer Study Derived Constraints

FFM, FFH



- Dollars
 - Attempt to keep total program costs constrained (e.g. Launch Vehicle)
- Mass Margin (over Delta Launch Vehicle capability)
 - FF Medium [non return, 70,000km (12 Re)] 25%
 - FFH Heavy (baseline, return, 550 km) 34%
- Volume
 - FF Medium & FFH Heavy have adequate volume for reference payload
 - Modular Accommodation
 - Late Access
- Other
 - FFH
 - Landing Site, S/C launch pad accessibility, power, propulsion, thermal



So...you
wanna
build a
WHAT??????





Workshop and Requirements



- Expect more detailed scientific requirements as a result of this workshop
- Please review the requirement matrices for Splinter Session 2 in which you will provide your proposed experimental scientific requirements for
 - FFM Spacecraft
 - FFH Spacecraft
 - Secondary Payloads of Opportunity
- Future studies will be based on these requirements



Scientific Requirements Matrix



| Spacecraft Capabilities | Mission Duration (months) | Sample Recovery (Yes / No) Why? | SC MicroGrav (DC, Vibration) Why? | is inflight variable G required? If so, what level? | Orbit (e.g., LEO, HEO, other) Why? | Orbit: Access to radiation types (proton, electron, GCR, etc), other key space environmental conditions | Can expt. be kept in "sleep mode" for delayed activation | Pressurized (yes/no) Life Support Needed (temp, rel. humidity, etc) | Access to payload (pre- launch; launch; post launch); timeframe (days / hours) | Special Needs: Contamination (internal, external, cross), chemicals, processes, etc. | Data / Video Requirements | Power (Peak, Orbit Average, Keep Alive (launch, DeOrbit, Safe Hold) | Thermo Loads (peak / ave); Range, Conditions (eg cryo, life, "hot"), provide temp range if possible | Mass Range (kg) | Volume range (m3) | Vibration (ranged needed) |
|--------------------------------|---------------------------|------------------------------------|---|--|---|--|---|---|--|---|--|---|--|-----------------|--|--|
| EXAMPLE: | 1-6 | No | 10E-5 to 10E-6 for 10 days; 15 days of .3 to .5 Gs | 15 days of .3 to .5 Gs - provide profile and why?(see previous column) | Desire GEO; both LEO and HEO acceptable | electron particles predominately; need exposure rate and duration | activate 12d after launch with telemetered data needs only; no ground commands needed | Self contained pressured environment with internal "sea level" atmosphere | Pre-launch 15 days; post launch none require - no return needed | Methanol reagent used | 500- 600bps downlink data; 10- 20 digital photo quality pictures 800x600 pixel resolutio | 500 mW ave; 800 mW turn- on only 30 sec.; | 1.5 W dissipated | 70-90 | 0.5-0.6m3 (80cmx80 cmx80cm) rectangle with test tubes | less than .5 G operating; 3 G non- operating |
| Research Goal A | | | | | | | | | | | | | | | | |
| Research Goal B | | | | | | | | | | | | | | | | |
| Research Goal C | | | | | | | | | | | | | | | | |
| Research Goal(etc.) | | | | | | | | | | | | | | | | |

What Size?





APPENDIX

- (1) TYPICAL LAUNCH VEHICLE SEQUENCING & PERFORMANCE
- (2) ECLSS
- (3) PARAMETRIC STUDY OF SPACE RADIATION EXPOSURES



OBPR-FFM

Delta 2920H & Mission Profile



**CONCEPT ONLY
NOT SPECIFIC TO OBPR**

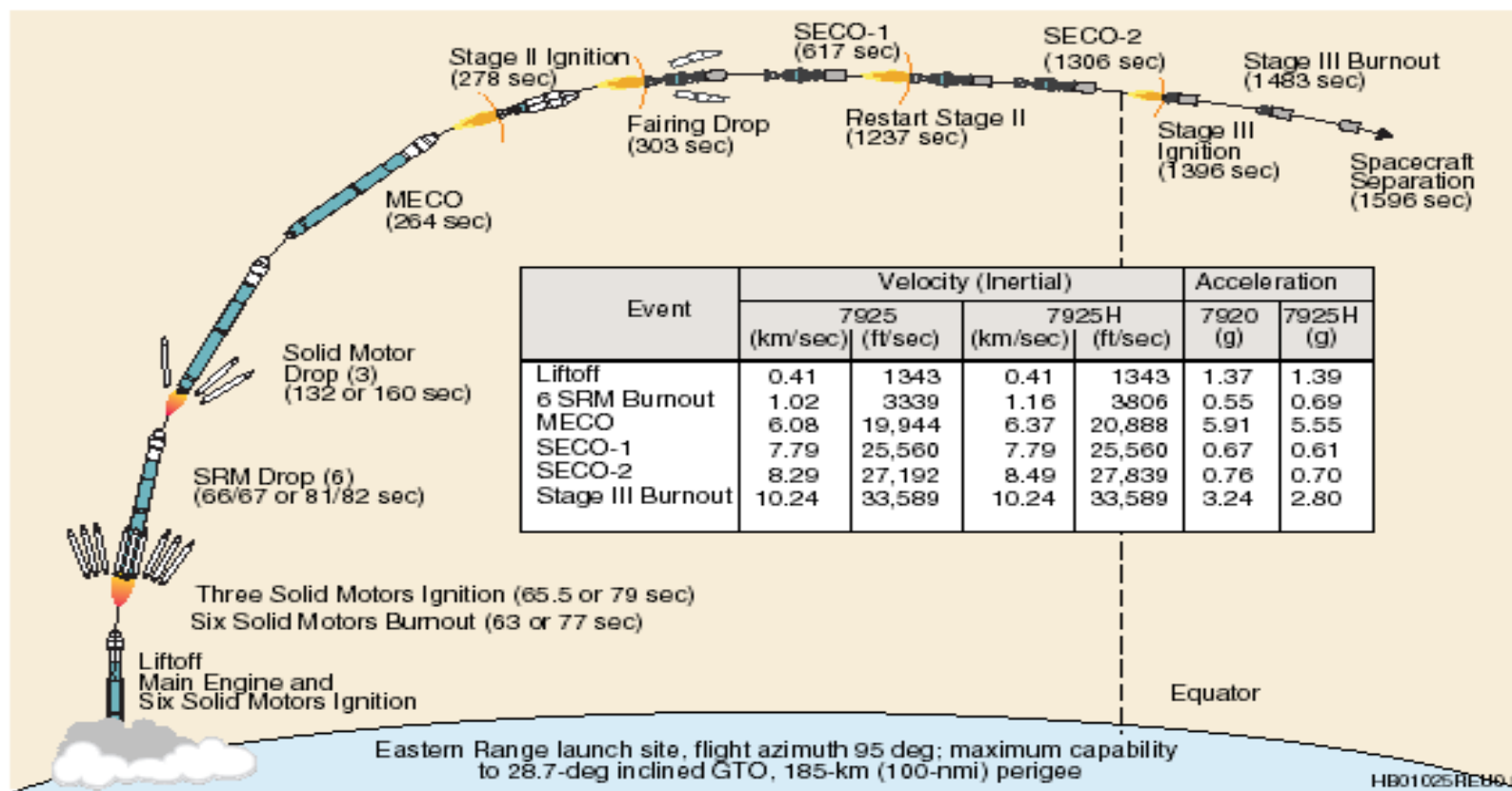


Figure 2-5. Typical Delta II 7925/7925H Mission Profile—GTO Mission (ER Launch Site)



OBPR-FFH

Delta 2920H & Mission Profile



**CONCEPT ONLY
NOT SPECIFIC TO OBPR**

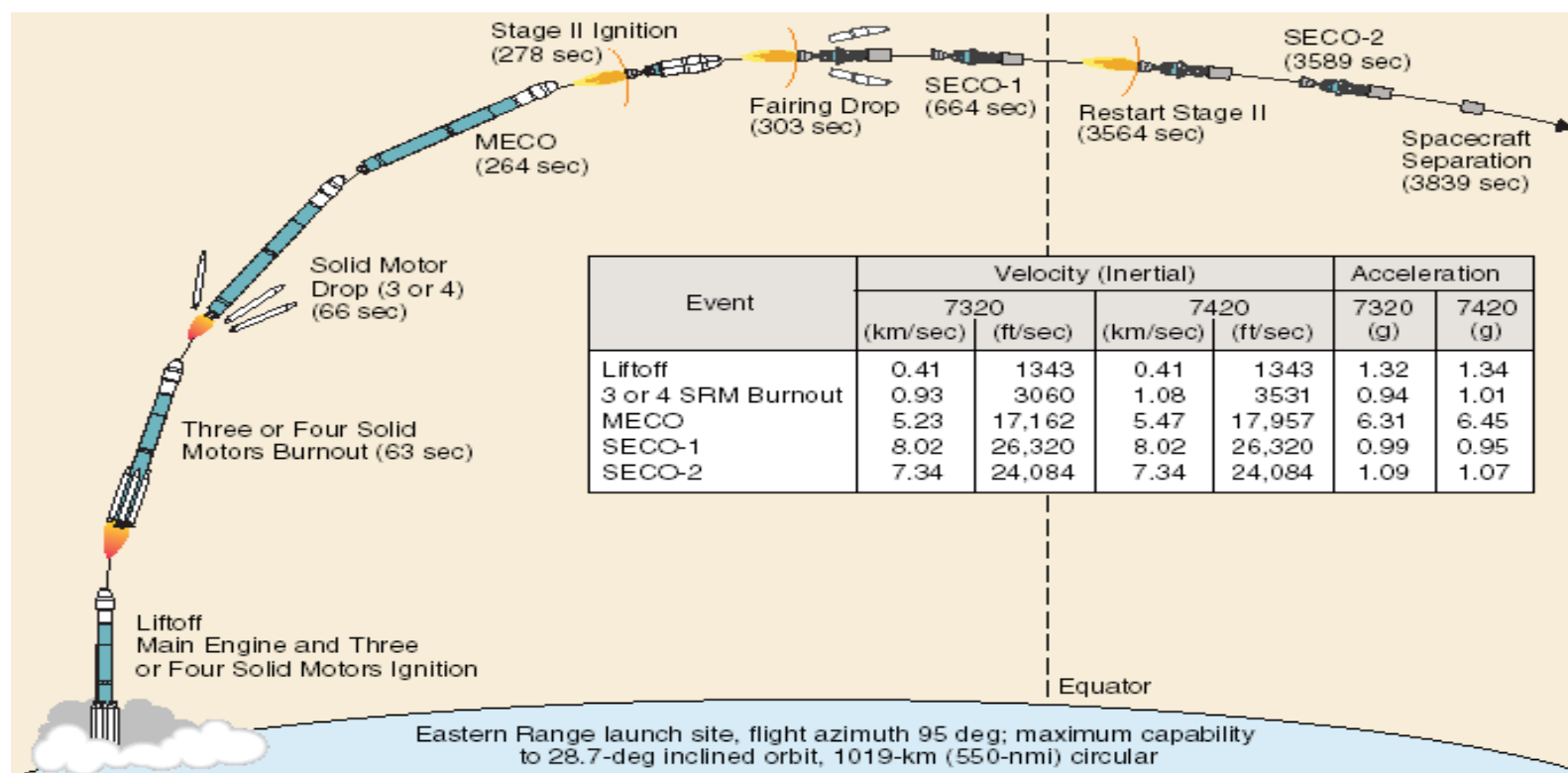


Figure 2-3. Typical Delta II 7320/7420 Mission Profile—Circular Orbit Mission (ER Launch Site)



Office of Biological and Physical Research FFM and FFH



CONCEPT ONLY
NOT SPECIFIC TO OBPR

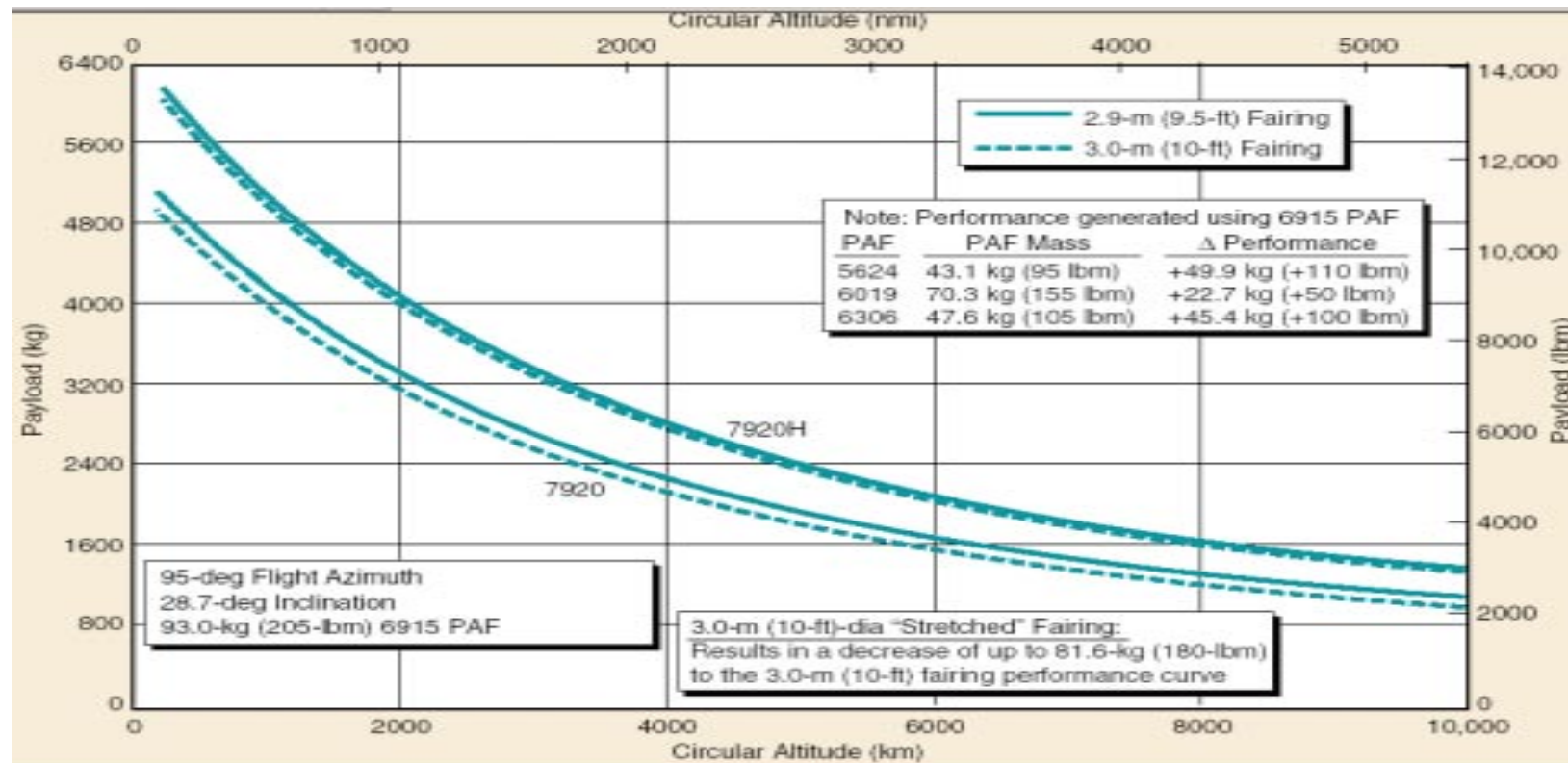


Figure 2-22. Delta II 7920/7920H Vehicle, Two-Stage Circular Orbit Altitude Capability—Eastern Launch Site



FFH RV ECLSS Flow Diagram

